Testing the Standard View of the Long-Run Unemployment-Inflation Relationship

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Abstract

The results in this paper, based on estimating and testing price equations for 30 countries, do not support the standard view of the long-run relationship between unemployment and inflation. They overwhelmingly reject the dynamics implied by the standard view. Wage equations are also estimated and tested. The paper also attempts to estimate the functional form of the relationship between measures of demand pressure and price and wage levels, but no strong conclusions emerge.

1 The Standard View

It seems safe to say that the concept of the natural rate of unemployment plays an important role in guiding policy actions and in framing how most macroeconomists think about the relationship between unemployment and inflation. The standard model of inflation, which, for example, is very clearly articulated in Mankiw's (1994) intermediate text, is the following. Begin with the supply equation:

$$y_t = y_t^* + \alpha(p_t - p_t^e), \quad \alpha > 0 \tag{1}$$

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where y is output, y^* is the natural rate of output, p is the price level, and p^e is the expected price level. All variables are in logs. Rewrite this equation with p_t on the left-hand side and subtract p_{t-1} from both sides:

$$p_t - p_{t-1} = p_t^e - p_{t-1} + \frac{1}{\alpha}(y_t - y_t^*) \tag{2}$$

or

$$\pi_t = \pi_t^e + \frac{1}{\alpha}(y_t - y_t^*) \tag{3}$$

where π is the actual rate of inflation and π^e is the expected rate. Replace $\frac{1}{\alpha}(y_t - y_t^*)$ with $-\beta(u_t - u_t^*)$, $\beta > 0$, where u is the actual unemployment rate and u^* is the natural rate, under the assumption that $u_t - u_t^*$ is highly negatively correlated with $y_t - y_t^*$. Finally, add supply shocks, ϵ_t, to arrive at the standard equation:

$$\pi_t = \pi_t^e - \beta(u_t - u_t^*) + \epsilon_t \tag{4}$$

Equation (4) by itself does not guarantee the absence of a long-run trade-off between unemployment and inflation. If, for example, π_t^e were 3 percent for all t, lowering u_t below the natural rate for all t would result in a finite increase in the rate of inflation. Similarly, if $\pi_t^e = \lambda\pi_{t-1}$, $\lambda < 1$, lowering u_t below the natural rate for all t would result in a finite increase in the rate of inflation. If, on the other hand, $\pi_t^e = \pi_{t-1}$, lowering u_t below the natural rate for all t would result in an ever increasing inflation rate. The same is true if $\pi_t^e = \lambda_1\pi_{t-1} + \lambda_2\pi_{t-2} + \lambda_3\pi_{t-3}$, where $\lambda_1 + \lambda_2 + \lambda_3 = 1$. Again, it seems safe to say that most views of inflationary expectation formation have coefficients like the λ_i's summing to one, which combined with (4) imply that there is no long-run trade-off between unemployment and inflation. The following equation will thus be used to represent the standard view (although in practice π_{t-1}

is likely to be replaced with a more complicated expression):

$$\pi_t = \pi_{t-1} - \beta(u_t - u_t^*) + \epsilon_t \tag{5}$$

In this context u_t^* is the "nonaccelerating inflation rate of unemployment" (Nairu).

The following statement in a policy-oriented book on European unemployment summarizes the standard view quite well: "We would not want to dissent from the view that there is no long-run trade-off between activity and inflation, so that macroeconomic policies by themselves can do little to secure a lasting reduction in unemployment."[1] For another example, Tobin (1980, p. 39) pointed out many years ago that "Most Keynesian economists accepted the thrust of the Phelps-Friedman analysis [of no long-run trade-off between unemployment and inflation]." [2] And for a very recent example, Krugman (1996, p. 37) in an article in the *New York Times Magazine* writes "The theory of the Nairu has been highly successful in tracking inflation over the last 20 years. Alan Blinder, the departing vice chairman of the Fed, has described this as the 'clean little secret of macroeconomics."'

The results in this paper, on the other hand, suggest that equations like (5) are *not* good approximations. The main aim of this paper is to present and discuss these results. Price equations are estimated and tested for 30 countries, and wage equations are estimated and tested for 19 countries.

To look ahead, if equations like (5) are not good approximations, then the standard

[1] Alogoskoufis et al. (1995), p. 124.

[2] Tobin (1972), however, presents a model in which there is a long-run trade-off at low inflation rates if nominal wage changes cannot be negative. Akerlof, Dickens, and Perry (1996) have recently expanded on this idea. They add a variable to an equation like (5) that is zero in periods of high inflation, but positive in periods of low inflation. In their model there is an absence of a long-run trade-off only at high inflation rates. The results in this paper call into question the Akerlof, Dickens, and Perry work because of its reliance on an equation like (5) as the base equation. If this equation is highly misspecified, its use as the base equation is questionable.

long-run unemployment-inflation story must be changed. The new story, however, does not have to imply that unemployment can be driven close to zero with only a modest long-run effect on the price level. There may be (and seems likely to be) a nonlinear relationship between the price level and unemployment at low levels of unemployment, where pushing unemployment further and further below some low level results in larger and larger increases in the price level. This nonlinearity would in effect bound unemployment above a certain level. An attempt is made in this paper to estimate this nonlinearity, but, as will be seen, there do not seem to be enough observations at very low unemployment rates to provide good estimates.

2 The Price and Wage Equations in Level Form

The theory that has guided the specification of the price and wage equations in this section was first presented in Fair (1974).[3] Firms are assumed to solve multiperiod profit maximization problems in which prices, wages, investment, employment, and output are decision variables. The maximization problem requires that a firm form expectations of various variables before the problem is solved. A firm's market share is a function of its price relative to the prices of other firms. A firm expects that it will gain (lose) customers if it lowers (raises) its price relative to the expected prices of other firms. Similarly, a firm expects that it will gain (lose) workers if it raises (lowers) its wage rate relative to the wage rates of other firms. The properties of the theoretical model are examined via simulation runs. Two of the properties that are relevant for present purposes are 1) a change in the expected prices (wages) of other firms leads the given firm to change its own price (wage) in the same direction,

[3] For more recent discussions see Fair (1984, Chapter 3), (1994, Chapter 2).

and 2) a firm responds to a decrease in demand by lowering its price and contracting output, and vice versa for an increase in demand. In this setup the natural decision variable is the price *level*. The objective of a firm is to choose its price level path (along with the paths of the other decision variables) that maximizes the multiperiod objective function.

Another, simpler, model in which the price level is the natural decision variable is a duopoly game with asymmetric information discussed in Tirole (1988, Section 9.1.1). The duopolists (firms 1 and 2) sell differentiated products, and firm 2 has incomplete information about firm 1's cost. The demand curves are symmetric and linear:

$$D_i(p_i, p_j) = a - bp_i + dp_j, \quad 0 < d < b \tag{6}$$

Both firms have constant marginal costs, c_1 and c_2, respectively, where c_2 is common knowledge, but only firm 1 knows c_1. Tirole shows that firm 2's profit-maximizing price is

$$p_2 = (a + dp_1^e + bc_2)/2b \tag{7}$$

where p_1^e is firm 2's expectation of firm 1's price. p_1^e depends, among other things, on firm 2's expectation of firm 1's marginal cost. Equation (2) says that firm 2's price is a function of the demand parameter a, firms 2's marginal cost c_2, and firm 2's expectation of firm 1's price p_1^e.

The price and wage equations postulated below are meant to be structural equations, where the wage rate is an explanatory variable in the price equation and the price is an explanatory variable in the wage equation. This treatment is contrary to the practice that began in the early 1980s, when it became common to focus instead on *reduced-form* price equations, i.e., price equations in which the wage rate is not an explanatory variable.[4] There is, however, no need to limit the analysis in this way, and important questions about the wage-price process are left unanswered when only reduced-form equations are estimated. In particular, questions about real wage behavior are ignored when the reduced-form approach is used.

The Basic Equations and the Real Wage Restriction

The two basic equations for estimation are the following:

$$p_t = \beta_0 + \beta_1 p_{t-1} + \beta_2(w_t - \lambda_t) + \beta_3 pm_t + \beta_4 D_t + \beta_5 t + e_t \tag{8}$$

$$w_t - \lambda_t = \gamma_0 + \gamma_1(w_{t-1} - \lambda_{t-1}) + \gamma_2 p_t + \gamma_3 p_{t-1} + \gamma_4 D_t + \gamma_5 t + u_t \tag{9}$$

p is the log of the price level, w is the log of the wage rate, and pm is the log of the import price level. D is some measure of demand pressure. λ_t is the log of Λ_t, where Λ_t is an estimate of the potential level of output per worker for period t. In the empirical work Λ_t is estimated from peak-to-peak interpolations of output per worker. The growth rate of Λ_t is an estimate of the growth rate of potential productivity. The change in $w_t - \lambda_t$ is the growth rate of the nominal wage rate less the growth rate of potential productivity. e_t and u_t are error terms.

The lagged price variable in equation (8) can be thought of as picking up expectational effects, which are in both theoretical models mentioned above—represented, for example, by p_1^e in equation (2) in the duopoly model. The wage and import price variables can be thought of as picking up cost effects, which are also in both models—represented by c_2 in equation (2). Finally, the demand variable picks up demand effects, which are in both models—represented by a in equation (2). The

[4]See, for example, Gordon (1980) and Gordon and King (1982).

wage equation is similar to the price equation, but it excludes the import price variable, which the price equation includes, and it includes the lagged wage variable, which the price equation excludes.

The time trend in equation (8) is meant to pick up any trend effects in the price level not captured by the other variables. Adding a time trend to an equation like (8) is similar to adding a constant term to an equation specified in terms of changes rather than levels. The time trend will also pick up any trend mistakes made in constructing λ_t. If, for example, $\lambda_t = \lambda_t^a + \delta t$, where λ_t^a is the correct variable to subtract from w_t to adjust for potential productivity, then the time trend will absorb this error. Similar considerations apply to the use of the time trend in equation (9).

Equations (8) and (9) can be used to solve for the reduced-form equation for $w_t - \lambda_t - p_t$ (conditional on pm_t and D_t), which is the real wage after adjusting for potential productivity. The form of the equation is:

$$w_t - \lambda_t - p_t = \delta_0 + \delta_1(w_{t-1} - \lambda_{t-1}) + \delta_2 p_{t-1} + \delta_3 pm_t + \delta_4 D_t + \delta_6 t + v_t \quad (10)$$

where the δ_i's are functions of the β_i's and γ_i's. v_t is the reduced-form error term; it is a function of the β_i's, the γ_i's, e_t, and u_t.

The second and third terms on the right-hand side of equation (10) can be rewritten $\delta_1(w_{t-1} - \lambda_{t-1} - p_{t-1})$ + $(\delta_1 + \delta_2)p_{t-1}$. Unless $\delta_1 = -\delta_2$, equation (10) implies that in the long run the real wage depends on the level of p, which is not sensible. Consequently, the restriction that $\delta_1 = -\delta_2$ was imposed in the final estimation. The restriction on the structural coefficients is

$$\gamma_3 = \frac{\beta_1}{1 - \beta_2}(1 - \gamma_2) - \gamma_1 \quad (11)$$

This "real wage" restriction was imposed on the estimation of the wage equation, where the values for β_1 and β_2 were taken from the final estimation of the price equation.

A More General Price Equation

A more general form of the price equation (8) is the following:

$$\begin{aligned} p_t &= \theta_0 + \theta_1 p_{t-1} + \theta_2(w_t - \lambda_t) + \theta_3 pm_t + \theta_4 D_t + \theta_5 t \\ &\quad + \theta_6 p_{t-2} + \theta_7(w_{t-1} - \lambda_{t-1}) + \theta_8 pm_{t-1} + e_t \end{aligned} \tag{12}$$

In the work below equation (8) will be tested against (12). If $\theta_6 = \theta_7 = \theta_8 = 0$, then (12) reduces to (8), and this is one of the hypotheses tested. The change form of the price equation, which is introduced in Section 3, will also be tested against (12).

The Demand Pressure Variables

As noted in Section 1, there seems likely to be a nonlinear relationship between p_t and the unemployment rate at low levels of the latter, and an attempt was made to estimate this nonlinearity. Five functional forms were tried for the unemployment rate. In addition, two other activity variables, both measures of the output gap, were tried in place of the unemployment rate. Six functional forms were tried for each gap variable.

Let u_t denote the unemployment rate, and let $u'_t = u_t - u^{min}$, where u^{min} is the minimum value of the unemployment rate in the sample period ($t = 1, \ldots, T$). The first form tried was linear, namely $D_t = u'_t$. The others were $D_t = 1/(u'_t + \alpha)$, where the values of α tried were .005, .010, .015, and .020. When, for example, α is .010, D_t is infinity when u'_t equals -.010, and so this form says that as the unemployment rate approaches 1.0 percentage point below the smallest value it reached in the sample period, the price level approaches infinity. The smaller is α, the more nonlinearity there is near the smallest value of the unemployment rate reached in the sample period.

For the first output-gap variable, a potential output series, denoted Y_t^*, was constructed from peak-to-peak interpolations of the level of output per worker and the number of workers per working-age population. (The peak-to-peak interpolation of output per worker is Λ_t mentioned above.) Define the gap, denoted G_t, as $(Y_t^* - Y_t)/Y_t^*$, where Y_t is the actual level of output, and let $G_t' = G_t - G^{min}$, where G^{min} is the minimum value of G_t in the sample period. For this variable the first form was linear, and the others were $D_t = 1/(G_t' + \alpha)$, where the values of α tried were .005, .010, .015, .020, and .050.

For the second output-gap variable, a potential output series was constructed by regressing, over the sample period, $\log Y_t$ on a constant and t. The gap G_t is then defined to be $\widehat{\log Y_t}$ - $\log Y_t$, where $\widehat{\log Y_t}$ is the predicted value from the regression. The rest of the treatment is the same as for the first output-gap variable.

Five functional forms for the unemployment rate and six each for the output-gap variables yields 17 different variables to try. In addition, each variable was tried both unlagged and lagged once separately, giving 34 different variables. This searching was done using the general form of the price equation, so that equation (12) was estimated 34 times, once for each demand pressure variable. This estimation work was done under the assumption of a first order autoregressive error term, and the autoregressive coefficient was estimated along with the other coefficients. The demand pressure variable chosen for the “final” equation was the one with the coefficient estimate of the expected sign and the highest t-statistic. No variable was chosen if the coefficient estimates of all the demand pressure variables were of the wrong sign. [5]

The same searching for the best demand pressure variable was done for the wage equation (9). This searching was done without imposing the coefficient restriction in (11) and under the assumption of a first order autoregressive error term.

The Final Specifications

Once the demand pressure variable was chosen for the price equation, three further specification decisions were made based on the estimates of equation (12) using the chosen demand pressure variable. The first decision is whether $w_t - \lambda_t$ or $w_{t-1} - \lambda_{t-1}$ should be included in the final specification, the second is whether pm_t or pm_{t-1} should be included, and the third is whether the autoregressive assumption about the error term should be retained. For each of the first two decisions the variable with the higher t-statistic was chosen provided its coefficient estimate was of the expected sign, and for the third decision the autoregressive assumption was retained if the autoregressive coefficient estimate was significant at the 5 percent level. If when tried separately both $w_t - \lambda_t$ and $w_{t-1} - \lambda_{t-1}$ had coefficient estimates of the wrong sign, neither was used, and similarly for pm_t and pm_{t-1}. [6]

Only one specification decision had to be made for the wage equation, namely whether the autoregressive assumption for the error term should be retained. The same decision criterion was used here as was used for the price equation.

[5] Data mining is, of course, a potential problem when searching like this. There is a bias in favor of finding significant demand pressure variables when none in fact belong. The main aim of this paper, however, is to compare different dynamic specifications, and this comparison is not likely to be affected much by the searching for demand pressure variables. Note that the searching is done using the general form, which encompasses both the level form and the change form, and so one form does not have an advantage over the other in this respect.

[6] When $w_{t-1} - \lambda_{t-1}$ is chosen, the coefficient restriction in (11) becomes $\gamma_3 = (\beta_1 + \beta_2)(1 - \gamma_2) - \gamma_1$.

χ^2 Tests of the Price Equation

The final specification of the price equation was subjected to a number of χ^2 tests. They consist of adding various variables to the equation and testing whether the addition is significant. An insignificant χ^2 value means the equation has passed the test. A χ^2 value will be said to be significant if its p-value is less than .01—a 1 percent confidence level.

The first test is to test the level form of the specification in (8) against the more general form in (12). [7] This is done by adding the variables p_{t-2}, $w_{t-1} - \lambda_{t-1}$, and pm_{t-1} to equation (8) and seeing if they are jointly significant.

The second test is to add even more lagged values to equation (8), namely the above three plus p_{t-3}, $w_{t-2} - \lambda_{t-2}$, and pm_{t-2}, and D_{t-1}. [8] Adding all these lagged values encompasses many different types of dynamic specifications,[9] and so it is a fairly general test of the dynamic specification of the equation.

The third test concerns the autoregressive properties of the error term. The search for the best demand pressure variable assumed a first order autoregressive error term. If for the final demand pressure variable chosen the autoregressive parameter was significant, the first order assumption was retained; otherwise, the error term was assumed not to be autoregressive. The third test is to estimate the equation

[7] When $w_{t-1} - \lambda_{t-1}$ is chosen as the wage variable in (8), then equation (12) should include $w_{t-1} - \lambda_{t-1}$ and $w_{t-2} - \lambda_{t-2}$, but not $w_t - \lambda_t$. Similarly, when pm_{t-1} is chosen as the import price variable in (8), equation (12) should include pm_{t-1} and pm_{t-2}, but not pm_t. For simplicity, the following discussion will assume that the wage and import price variables in (8) are unlagged. If the wage variable is in fact lagged, then the wage lags in the discussion should all be increased by one. Similarly, if the import price variable is lagged, the import price lags in the discussion should all be increased by one.

[8] D_{t-1} will always mean the chosen demand pressure variable lagged one more period than it appears in the equation. If, for example, the chosen variable is lagged once, then D_{t-1} is the chosen variable lagged twice.

[9] See Hendry, Pagan, and Sargan (1984) for a general discussion.

under the assumption of a fourth order autoregressive error term and see if the extra autoregressive coefficients are jointly significant. If the first order assumption has been used in the basic estimation, three additional autoregressive coefficients are estimated for the third test; otherwise, four are. This third test is to see if the serial correlation properties of the error term have been properly accounted for.

For the fourth test the value of the wage rate *led* one period was added to the equation. This can be looked upon as a test of the expectation mechanism. If the future value is significant, this is evidence in favor of the rational expectations hypothesis. [10]

The fifth test is a stability test due to Andrews and Ploberger (1994) and discussed in Fair (1994, Chapter 4). This test does not require that a break point be chosen *a priori*, just a range in which the structural break occurred if there was one. Depending on the data availability for a country, the break period was assumed to begin between 32 and 60 quarters after the beginning of the estimation period and to end between 32 and 60 quarters before the end of the estimation period. For example, for the United States, the estimation period is 1954:1–1995:3, and the break period was taken to be 1969:1–1979:4.

The sixth test differs from the first four in that variables are in effect subtracted from equation (8) rather than added. The test is of the joint hypothesis that in equation (8) $\beta_1 + \beta_2 + \beta_3 = 1$ and $\beta_5 = 0$. If the only nominal variable on the right-hand side of equation (8) were the lagged price level, the first restriction would be $\beta_1 = 1$,

[10] See Fair (1994, Chapter 4) for a discussion of this test. When future values are added to an equation, consistent estimates can be obtained using Hansen's (1982) method of moments estimator. In the present context, with only one lead, this estimator is just 2SLS, which, as discussed below, is the method used in this paper.

and under this hypothesis the equation would become

$$p_t = \beta_0 + p_{t-1} + \beta_4 D_t + e_t, \tag{13}$$

Equation (13) is analogous to equation (5) except that the level of p is used in place of the change in p. It is the original Phillips curve. The sixth test is thus roughly a test of equation (8) versus the original Phillips curve.

χ^2 Tests of the Wage Equation

The first test for the wage equation is of the coefficient restriction in (11), the "real wage" restriction. All the remaining tests were performed with this restriction imposed.

The second test adds the lagged values $w_{t-2} - \lambda_{t-2} - p_{t-2}$, $w_{t-3} - \lambda_{t-3} - p_{t-3}$, and D_{t-1}. Again, this is a fairly general test of the dynamic specification. Adding $w_{t-2} - \lambda_{t-2} - p_{t-2}$ instead of $w_{t-2} - \lambda_{t-2}$ and p_{t-2} separately and adding $w_{t-3} - \lambda_{t-3} - p_{t-3}$ instead of $w_{t-3} - \lambda_{t-3}$ and p_{t-3} separately preserves the "real wage" restriction that the real wage in the long run does not depend on the level of p.

The third test is to estimate the equation under the assumption of a fourth order autoregressive process of the error term and to see if the extra autoregressive coefficients are jointly significant. The same procedure was followed here as was followed for the price equation.

The fourth test is the Andrews-Ploberger stability test. Again, the same procedure was followed here as was followed for the price equation.

The fifth test differs from the first three in that variables are in effect subtracted from equation (9) rather than added. The test is of the joint hypothesis that in equation

(9) $\gamma_1+\gamma_2+\gamma_3 = 1$ and $\gamma_5 = 0$. The real wage restriction (11) and $\gamma_1+\gamma_2+\gamma_3 = 1$ imply that $\gamma_2 = 1$. Under the joint hypothesis, equation (9) thus becomes

$$w_t - \lambda_t - p_t = \gamma_0 + \gamma_1(w_{t-1} - \lambda_{t-1} - p_{t-1}) + \gamma_4 D_t + u_t \tag{14}$$

One can think of this equation as going with equation (13)—both are based on the right-hand side nominal coefficients summing to one.

The Data and Estimation Technique

The data are described in Fair (1994), and this description will not be repeated here. Quarterly data were collected for 14 countries (to be called the "quarterly" countries) and annual data were collected for 16 others (to be called the "annual" countries). The main sources of data for the countries other than the United States are IFS and OECD. The price variable is the GDP or GNP deflator, and the wage variable is the nominal wage variable from the IFS. For the United States the price variable is the private non-farm price index, and the wage variable is constructed using employment data from the Bureau of Labor Statistics and wage income data from the national income and product accounts. [11]

The quality of the data varies across countries, and the results for the individual countries should not necessarily be weighted equally. In particular, the results for the countries with only annual data should probably be weighted less. Also, the wage data are probably not in general as good as the price data. The reason there are fewer countries with estimated wage equations than estimated price equations is simply

[11] In terms of the notation in Fair (1994), for the United States p is PF, w is WF, λ is LAM, and pm is PIM. For the other countries p is PY, w is W, λ is LAM, and pm is PM. For the United States the wage variable in equation (8) (but not in equation (9)) is inclusive of employer social security taxes.

because of data limitations. [12]

The estimation technique was 2SLS for the quarterly countries and OLS for the annual countries. For 2SLS, the endogenous variables were taken to be p_t, w_t, D_t, and pm_t. This means that the price and wage equations were assumed to be imbedded in a larger model, where D_t and pm_t are endogenous. The variables used for the first stage regressors are the main predetermined variables in the individual country models in Fair (1994). The list of these variables for each country is available from the author upon request.

The value computed for each χ^2 test is $(S^{**} - S^*)/\sigma^2$, where S^{**} is the value of the minimand (2SLS or OLS) before the addition, S^* is the value of the minimand after the addition, and σ^2 is the estimated variance of the error term after the addition. Under fairly general conditions, as discussed in Andrews and Fair (1988), this value is distributed as χ^2 with k degrees of freedom, where k is the number of variables added. [13]

The Results

The results for the price equation are presented in Tables 1 and 2. The coefficient estimates of the final specification are presented in Table 1, and the test results are presented in Table 2. From Table 1 it can be seen that of the 20 countries for which a

[12] A few of the tests were slightly different for the annual countries because of the smaller number of observations. First, when searching for the best demand pressure variable, the equations were not assumed to have a serially correlated error and the demand pressure variables lagged once were not tried. Second, when testing for serial correlation, the autoregressive process was taken to be of order 3 rather than 4. Third, for the structural stability test only one possible break point was assumed (as opposed to a range of possible break points), which means that the AP test is just a χ^2 test.

[13] When a coefficient restriction is imposed rather than variables added, S^* is the value of the minimand before the restriction is imposed, and S^{**} is the value with the restriction imposed. σ^2 is the estimated variance before the restriction is imposed.

Table 1
Estimates of the Price Equation

$$p_t = \beta_0 + \beta_1 p_{t-1} + \beta_2(w_t - \lambda_t) + \beta_3 pm_t + \beta_4 D_t + \beta_5 t$$

	Best D	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$	$\hat{\rho}$	SE	DW	Sample
Quarterly											
US	U_{-1}(.020)	.020	.835	.112	.042	.00046	.00016	b	.00357	1.81	541-953
		(1.51)	(46.26)	(5.15)	(16.72)	(6.94)	(4.02)				
CA	$G2_{-1}$(lin)	-.074	.924	.010	.022	-.134	.00053	.512	.00538	2.24	661-944
		(-0.67)	(14.45)	(0.22)	(1.26)	(-5.02)	(1.71)	(5.49)			
JA	$G2$(lin)	-.924	.687	.186	.016	-.189	.00131	.679	.00681	2.18	673-944
		(-2.88)	(7.23)	(2.76)	(1.47)	(-3.04)	(2.85)	(6.90)			
AU	$G1$(.020)	-.812	.821	[a].114	[a].030	.00035	.00048	−.374	.00985	1.97	712-934
		(-2.75)	(13.42)	(2.62)	(1.92)	(1.52)	(1.28)	(-3.71)			
FR	$G2_{-1}$(.005)	-.763	.820	.101	[a].021	.000042	.00052	.326	.00480	1.78	761-934
		(-2.56)	(16.55)	(2.57)	(1.30)	(1.61)	(1.68)	(2.51)			
GE	$G2_{-1}$(lin)	-.385	.877	[a].037	.015	-.079	.00052	b	.00310	1.90	691-944
		(-2.06)	(26.05)	(1.76)	(4.04)	(-5.99)	(4.98)				
IT	$G2$(lin)	-.182	.892	.015	.047	-.164	.00137	.297	.00627	1.95	721-942
		(-1.73)	(23.66)	(0.42)	(4.92)	(-4.11)	(3.78)	(2.78)			
NE	none	-1.520	.493	.319	.090	–	.00034	b	.00791	1.71	782-943
		(-2.64)	(4.42)	(2.29)	(5.07)		(0.61)				
ST	$G2_{-1}$(lin)	-.064	.903	c	[a].023	-.093	.00076	.627	.00309	1.64	711-934
		(-1.48)	(21.52)		(2.11)	(-4.05)	(1.99)	(6.29)			
UK	none	-1.022	.592	.427	.044	–	-.00139	.558	.00875	2.30	661-944
		(-4.74)	(8.26)	(4.51)	(2.43)		(-2.51)	(6.31)			
FI	U(.010)	-.124	.845	.119	.024	.00025	.00030	b	.00720	1.92	761-933
		(-1.76)	(11.43)	(1.37)	(2.24)	(3.06)	(0.75)				
AS	$G1_{-1}$(.015)	.044	.977	c	.020	.00028	-.00027	b	.01093	2.06	711-943
		(0.91)	(34.55)		(1.37)	(2.75)	(-0.89)				
SO	none	-.123	.941	c	.031	–	.00097	b	.01774	2.21	621-943
		(-3.18)	(68.45)		(2.66)		(3.99)				
KO	$G2_{-1}$(.050)	-.606	.639	.260	.114	.00434	-.00393	-.241	.03572	1.95	661-943
		(-3.16)	(5.87)	(2.99)	(3.36)	(3.12)	(-2.62)	(-2.07)			

Table 1 (continued)

	Best D	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$	SE	DW	Sample
Annual										
BE	$G2$(.005)	-1.271	.549	.236	.018	.00014	.01047	.01228	1.14	66-92
		(-4.73)	(5.80)	(5.01)	(0.72)	(1.76)	(3.24)			
DE	U(.005)	-2.013	.578	.364	.060	.000097	-.00244	.00760	2.09	67-92
		(-9.53)	(10.22)	(11.18)	(2.93)	(1.94)	(-1.10)			
NO	U(lin)	-.351	.540	d	.350	-.761	.01279	.02633	1.23	66-92
		(-1.70)	(4.18)		(3.87)	(-1.18)	(1.87)			
SW	U(lin)	-1.733	.541	.255	.117	-.463	.00945	.01503	1.93	66-92
		(-2.76)	(5.93)	(2.12)	(5.40)	(-0.89)	(1.89)			
GR	$G1$(.005)	-.237	.683	.078	.221	.00031	-.00106	.02274	1.66	64-92
		(-1.32)	(17.31)	(1.31)	(4.08)	(2.19)	(-0.20)			
IR	none	-.374	.611	.345	[a].077	–	-.00361	.02590	1.71	72-91
		(-1.31)	(5.44)	(1.88)	(0.67)		(-0.57)			
PO	none	-.318	.756	c	.199	–	.01356	.02350	1.41	62-92
		(-4.82)	(35.04)		(9.02)		(6.59)			
SP	$G1$(.050)	-.703	.781	.244	d	.00436	-.01369	.01361	1.94	64-92
		(-5.78)	(21.30)	(15.04)		(3.66)	(-3.75)			
NZ	none	-1.156	.599	.243	[a].147	–	.00185	.02871	1.52	62-92
		(-4.55)	(11.80)	(3.13)	(3.06)		(0.33)			
CO	$G1$(lin)	-3.237	.407	c	.107	-.311	.10746	.02032	2.39	72-92
		(-3.17)	(3.05)		(2.06)	(-1.32)	(3.27)			
JO	none	-.164	.698	c	.218	–	.00810	.03950	1.86	71-93
		(-0.84)	(7.92)		(4.12)		(1.30)			
SY	none	-.320	.868	c	.056	–	.01298	.07553	1.34	65-93
		(-0.77)	(10.57)		(0.90)		(1.02)			
MA	$G2$(lin)	-.192	.650	c	.065	-.708	.00935	.04214	1.87	72-93
		(-1.40)	(5.64)		(0.71)	(-2.67)	(1.92)			
PA	none	-.257	.635	c	.170	–	.01077	.02152	1.57	76-93
		(-0.67)	(4.46)		(2.37)		(0.89)			
PH	none	-.128	.711	c	.213	–	.00606	.05419	1.53	62-93
		(-0.45)	(10.03)		(4.60)		(0.67)			
TH	$G1$(lin)	-.634	.182	c	.339	-.089	.02094	.02532	1.46	62-92
		(-5.91)	(1.84)		(7.52)	(-0.40)	(5.97)			

t-statistics are in parentheses.
[a]Variable lagged once. [b]ρ taken to be 0. [c]No wage data. [d]Coefficient taken to be 0.
ρ not estimated for annual countries.
U = unemployment rate, $G1$ = first output-gap variable, $G2$ = second output-gap variable.
The number in parentheses following U, $G1$, and $G2$ is the value of α used, where lin means the linear form.
$\hat{\beta}_4$ is expected to be negative when the linear form is used and positive otherwise.

US=United States, CA=Canada, JA=Japan, AU=Austria, FR=France, GE=Germany, IT=Italy, NE=Netherlands, ST=Switzerland,UK=United Kingdom, FI=Finland, AS=Australia, SO=South Africa, KO=Korea, BE=Belgium, DE=Denmark, NO=Norway,SW=Sweden, GR=Greece, IR=Ireland, PO=Portugal, SP=Spain, NZ=New Zealand, CO=Colombia, JO=Jordan,SY=Syria, MA=Malaysia, PA=Pakistan, PH=Philippines, TH=Thailand

Table 2
Test Results for the Price Equation

	Level vs. General Form p-val	More Lags p-val	RHO+ p-val	Lead p-val	Stability AP (df) λ	Sum=1 & no *t* in Level Form p-val	Change vs. General Form p-val	Change vs. General Form (No *t*) p-val	Sum=1 in Change Form p-val
Quarterly									
US	.639	.805	.312	.509	6.67 (6) 2.87	.000	.000	.000	.000
CA	.554	.590	.427	.099	*19.67 (7) 1.94	.041	.003	.023	.002
JA	.570	.012	.291	.023	6.79 (7) 1.61	.000	.000	.006	.038
AU	.251	.444	.109	.187	1.40 (7) 1.62	.034	.000	.000	.000
FR	.165	.500	.191	.012	7.40 (7) 1.48	.001	.002	.002	.012
GE	.506	.200	.069	.479	8.53 (6) 2.46	.000	.000	.000	.096
IT	.115	.396	.424	.012	8.44 (7) 1.49	.000	.001	.004	.000
NE	.229	.688	.504	.198	3.95 (5) 1.06	.000	.000	.000	.011
ST	.000	.003	.001	c	2.26 (6) 1.62	.077	.000	.007	.000
UK	.033	.098	.082	.005	*25.58 (6) 1.94	.006	.001	.001	.783
FI	.990	.573	.212	.449	*12.92 (6) 1.40	.686	.001	.000	.036
AS	.295	.024	.008	c	1.63 (5) 1.81	.000	.000	.000	.000
SO	.295	.612	.116	c	*9.80 (4) 2.89	.000	.000	.000	.000
KO	.080	.361	.001	.486	*12.18 (7) 1.88	.003	.011	.038	.112
Annual									
BE	.000	.001	.001	.242	*29.32 (6) 1.00	.001	.020	.019	.007
DE	.390	.190	.110	.027	5.89 (6) 1.00	.000	.000	.000	.266
NO	.099	.663	.608	.868	*16.64 (5) 1.00	.003	.141	.184	.018
SW	.002	.000	.006	.032	2.31 (6) 1.00	.000	.000	.015	.190
GR	.024	.157	.605	.492	*15.92 (6) 1.00	.039	.003	.002	.507
IR	.832	.549	.356	.160	3.69 (5) 1.00	.844	.230	.110	.948
PO	.346	.477	.414	c	*7.08 (4) 1.00	.000	.002	.179	.270
SP	.079	.106	.502	.724	*13.42 (5) 1.00	.000	.000	.000	.058
NZ	.005	.012	.479	.145	3.80 (5) 1.00	.517	.000	.000	.282
CO	.044	.001	.289	c	5.90 (5) 1.00	.000	.000	.033	.010
JO	.402	.561	.987	c	*11.39 (4) 1.00	.369	.062	.023	.001
SY	.009	.018	.011	c	2.60 (4) 1.00	.011	.117	.107	.159
MA	.086	.007	.014	c	*13.20 (5) 1.00	.001	.019	.035	.000
PA	.262	.621	.308	c	5.20 (4) 1.00	.056	.046	.043	.045
PH	.004	.011	.013	c	*16.41 (4) 1.00	.061	.005	.003	.003
TH	.204	.009	.000	c	1.76 (5) 1.00	.000	.004	.957	.000

*Significant at the one percent level. [c]No wage data.
AP=Andrews-Ploberger statistic, df=degrees of freedom.
λ depends on the observations chosen for the first and last possible break points.

demand pressure variable was used, [14] the functional form was linear for 10 of them. The chosen variable was the unemployment rate for 5 of them, the first output-gap variable for 6 of them, and the second output-gap variable for the remaining 9. There is thus no strong pattern here, although some edge for the linear form and the second output-gap variable. The good showing for the linear form shows the difficulty of estimating the point at which the relationship between the price level and unemployment becomes nonlinear.

Of the 10 countries with no demand pressure variable in Table 1, three of them—the Netherlands, the United Kingdom, and New Zealand—have wage equations in Table 3 with demand pressure variables. For these three countries demand pressure affects prices by affecting wages, which affect prices. South Africa is the only quarterly country for which there are no demand pressure effects on the price level.

The price equation does well in the first four tests in Table 2. The level form is rejected (at the 1 percent confidence level) in favor of the general form in only 1 of the 14 quarterly cases and in only 5 of the 16 annual cases. When more lags are added for the second test, there is still only 1 quarterly rejection and 5 annual rejections. For the autoregressive error term test, there are 2 quarterly rejections and 3 annual rejections. There is 1 quarterly rejection for the leads test and no annual rejections.

Overall, this is a very strong showing. Particularly important for present purposes are the good results for the first two tests. If the level form has bad dynamics, one would not expect it to do well when lagged values are added, but it does do well in that the lagged values are rarely significant. The results are not quite as strong for

[14] Remember, no demand pressure variable was included if the coefficient estimates of all the demand pressure variables were of the wrong sign.

the stability test. There are 5 quarterly rejections and 8 annual rejections.

For the largest developed countries, there are no rejections for any of the five tests for the United States, Japan, France, Germany, and Italy. There is a rejection for the leads tests for the United Kingdom, and the U.K. equation fails the stability test.

Moving on to the sixth test, the hypothesis that the coefficients of the right-hand side nominal variables sum to one and that the coefficient of the time trend is zero is rejected at the 1 percent level in 10 of the 14 quarterly cases and 9 of the 16 annual cases. At the 5 percent level there are 12 quarterly rejections and 10 annual rejections. There is thus not much support for this special case of equation (8), namely an equation like the original Phillips curve.

The last three tests in Table 2 are discussed in the next section.

The coefficient estimates of the final specification of the wage equation are presented in Table 3, and the test results are presented in Table 4. From Table 3 it can be seen that of the 13 countries for which a demand pressure variable was used, the functional form was linear for 8 of them. The chosen variable was the unemployment rate for 6 of the 13 and the second output-gap variable for the other 7. There is thus an edge for the linear form and the second output-gap variable, somewhat stronger here than for the price equation. This thus further shows the difficulty of estimating nonlinearities between demand pressure and price and wage levels.

The wage equation does well in the first three tests in Table 4. The real wage restriction is rejected in only 3 of the 11 quarterly cases and in none of the 8 annual cases. When lags are added for the second test, there are 2 quarterly rejections and no annual rejections. For the autoregressive error term test, there are 3 quarterly

Table 3
Estimates of the Wage Equation

$$w_t - \lambda_t = \gamma_0 + \gamma_1(w_{t-1} - \lambda_{t-1}) + \gamma_2 p_t + \gamma_3 p_{t-1} + \gamma_4 D_t + \gamma_5 t$$

	Best D	$\hat{\gamma}_0$	$\hat{\gamma}_1$	$\hat{\gamma}_2$	$\hat{\gamma}_3$	$\hat{\gamma}_4$	$\hat{\gamma}_5$	$\hat{\rho}$	SE	DW
Quarterly										
US	none	-.082	.867	.660	-.547	–	.00014	b	.00688	1.76
		(-5.72)	(28.32)	(9.47)			(2.70)			
CA	none	.104	.952	1.091	-1.038	–	-.00004	b	.00814	1.59
		(1.75)	(32.52)	(13.38)			(-0.60)			
JA	none	.482	.893	1.101	-.979	–	-.00034	b	.00934	1.95
		(2.66)	(22.55)	(11.15)			(-2.23)			
AU	$G2_{-1}$(lin)	2.211	.656	.442	-.158	-.178	.00063	-.659	.01560	1.66
		(4.21)	(8.23)	(2.27)		(-7.52)	(2.81)	(-7.52)		
FR	none	.501	.934	1.159	-1.079	–	-.00018	b	.00905	1.49
		(1.30)	(18.04)	(4.40)			(-0.94)			
GE	none	1.465	.829	1.597	-1.375	–	-.00016	-.280	.01183	2.12
		(2.68)	(13.14)	(4.01)			(-0.81)	(-2.68)		
IT	U_{-1}(lin)	.217	.915	1.157	-1.057	-.259	-.00038	b	.01337	1.74
		(1.50)	(19.54)	(7.99)		(-1.60)	(-0.84)			
NE	$G2_{-1}$(.010)	2.344	.412	.018	.299	.00007	.00240	.546	.00549	1.94
		(7.68)	(5.87)	(0.19)		(1.02)	(12.81)	(4.51)		
UK	$G2_{-1}$(.015)	.264	.913	.854	-.762	.00044	-.00011	b	.01096	2.27
		(2.68)	(26.00)	(9.69)		(2.76)	(-1.32)			
FI	U_{-1}(lin)	.115	.834	.528	-.382	-.099	-.00001	-.349	.00966	1.96
		(1.83)	(11.09)	(2.47)		(-2.55)	(-0.07)	(-2.50)		
KO	$G2$(.020)	.292	.713	.514	-.294	.00363	.00662	b	.03186	1.92
		(2.87)	(15.68)	(7.83)		(4.57)	(8.41)			
Annual										
BE	U(lin)	-1.752	1.394	.740	-1.207	-1.419	.00082		.01447	1.77
		(-3.06)	(11.62)	(3.64)		(-5.71)	(2.30)			
DE	U(lin)	.357	.942	1.269	-1.187	-.664	.00051		.01406	2.18
		(0.45)	(6.75)	(7.26)		(-3.65)	(0.78)			
NO	U(lin)	.924	.729	.376	-.391	-2.170	.02269		.03003	1.11
		(1.83)	(7.82)	(2.36)		(-2.80)	(3.93)			
SW	U(.005)	4.008	.268	.441	.138	.00047	.00701		.01853	1.74
		(5.30)	(2.10)	(3.20)		(4.79)	(2.24)			
GR	$G2$(lin)	.283	.920	.930	-.869	-.127	.00410		.04110	1.53
		(0.52)	(8.01)	(4.14)		(-0.87)	(0.50)			
IR	none	.076	.976	.537	-.544	–	-.00113		.02530	1.66
		(0.25)	(5.81)	(3.10)			(-0.50)			
SP	$G2$(lin)	.419	.886	1.323	-1.220	-.115	.00364		.02018	2.14
		(2.94)	(17.78)	(8.03)		(-1.57)	(1.28)			
NZ	$G2$(.005)	.334	.907	.824	-.767	.00038	.00330		.03129	1.22
		(0.85)	(11.74)	(6.30)		(2.04)	(1.17)			

t-statistics are in parentheses.
[b] ρ taken to be 0.
See the notes to Table 1.
$\hat{\gamma}_4$ is expected to be negative when the linear form is used and positive otherwise.

Table 4
Test Results for the Wage Equation

	Real Wage Restr. p-val	Lags p-val	RHO+ p-val	Stability AP (df) λ	Eq. (14) p-val
Quarterly					
US	.922	.075	.000	*8.00 (4) 2.87	.000
CA	.290	.023	.060	*18.97 (4) 1.94	.477
JA	.000	.862	.807	2.10 (4) 1.88	.000
AU	.943	.004	.036	7.38 (6) 1.63	.016
FR	.684	.030	.195	*21.05 (4) 1.48	.483
GE	.294	.018	.011	1.55 (5) 2.46	.100
IT	.550	.511	.047	3.28 (5) 1.49	.501
NE	.552	.303	.988	1.40 (6) 1.06	.000
UK	.000	.290	.641	*9.82 (5) 1.94	.208
FI	.020	.001	.003	*17.31 (6) 1.40	.019
KO	.000	.122	.268	*9.67 (5) 1.88	.000
Annual					
BE	.154	.658	.321	6.88 (5) 1.00	.000
DE	.424	.788	.053	1.94 (5) 1.00	.080
NO	.622	.107	.043	*13.23 (5) 1.00	.000
SW	.232	.234	.315	4.61 (5) 1.00	.000
GR	.331	.435	.235	*13.90 (5) 1.00	.871
IR	.913	.075	.000	0.98 (4) 1.00	.003
SP	.269	.419	.085	*11.69 (5) 1.00	.135
NZ	.138	.135	.018	*10.34 (5) 1.00	.341

*Significant at the one percent level.
See the notes to Table 2.

rejections and 1 annual rejection. As with the price equation, the results are not as strong for the stability test. There are 6 of 11 quarterly rejections and 4 of 8 annual rejections. A key result for purposes of this paper is the strong showing for the real wage restriction. The data generally support the hypothesis that in the long run the real wage is not a function of the price level.

The results are mixed for the fifth test, which is a test of (14) versus (9) (with the real wage restriction imposed on (9)). The hypothesis that the coefficients of the right-hand side nominal variables sum to one and that the coefficient of the time trend is zero is rejected at the 1 percent level in 4 of the 11 quarterly cases and 4 of the 8 annual cases. At the 5 percent level there are 6 quarterly rejections and still 4 annual rejections. There is thus at least some support for the specification in (14). Overall, it is about a tie between equations (9) and (14).

3 The Price Equation in Change Form

The price equation in "change form" is:

$$\begin{aligned} p_t - p_{t-1} = \beta_0 + \beta_1(p_{t-1} - p_{t-2}) + \beta_2(w_t - \lambda_t - w_{t-1} + \lambda_{t-1}) \\ +\beta_3(pm_t - pm_{t-1}) + \beta_4 D_t + e_t \end{aligned} \tag{15}$$

This equation is a special case of the general price equation (12), with $\theta_1 + \theta_6 = 1$, $\theta_2 = -\theta_7$, $\theta_3 = -\theta_8$, and $\theta_5 = 0$. Note that equation (15) is not the first difference of equation (8). The first difference of (8) would have $D_t - D_{t-1}$ on the right-hand side rather than just D_t.

Given the rather strong results for the level form of the price equation in Table 2, it would be surprising if the change form also did well. The first test of the change form was to test it against the general form. This is done by adding the variables p_{t-1}, $w_{t-1} - \lambda_{t-1}$, pm_{t-1}, and t to equation (15) and testing for their joint significance. This is a key test of equation (15). If the added variables are significant, this is clear evidence against the change-form restrictions.

The second test compares the change form with the general form but excludes the time trend (t) from the general form. The second test adds the variables p_{t-1}, $w_{t-1} - \lambda_{t-1}$ and pm_{t-1} to (15) and tests for their joint significance. In cases in which the first test rejects the change form, this second test helps to determine whether the rejection is due solely to the time trend's being in the general form but not in the change form.

The third test is of the hypothesis that in equation (15) $\beta_1 + \beta_2 + \beta_3 = 1$. If the only nominal variable on the right-hand side of equation (15) were the change in the lagged price level, the equation would become under this hypothesis

$$p_t - p_{t-1} = \beta_0 + (p_{t-1} - p_{t-2}) + \beta_4 D_t + e_t \tag{16}$$

Equation (16) is analogous to equation (5); it is consistent with the standard view. [15]

The Results

The results of the first test are presented in the third-to-last column in Table 2. The change form is overwhelmingly rejected in favor of the general form. The hypothesis is rejected in 13 of the 14 of the quarterly cases (for all but Korea), and in many of these cases the p-values are zero to three decimal places (very large χ^2 values). The hypothesis is rejected in 9 of the 16 annual cases.

The results for the second test, presented in the second-to-last column, show that at least for the quarterly countries the strong rejection of the change form is not due to the time trend's presence in only the general form. For the second test the change form is rejected in 12 of the 14 quarterly cases. For the annual countries there are 5 of 16 rejections compared to 9 of 16 before. There are, however, only 5 p-values that are greater than .05 for the annual countries for the second test, so that overall there is not much support for the change form for the annual countries even when the time trend is excluded from the general form.

[15] Of all the tests in this paper, this one may be the most likely to suffer from the problem that the asymptotic distribution that is used for the tests may not be a good approximation of the exact distribution. To check for this, the accuracy of the asymptotic distribution is examined in the Appendix for the U.S. equation. The results suggest that the asymptotic distribution is in fact a quite good approximation in this case.

Given the strong rejection of the change form, the third test is perhaps not of much interest, since it tests a restriction within the change form specification. For what they are worth, however, the results are presented in the last column in Table 2. The summation restriction is rejected in 7 of the 14 quarterly cases and 5 of the 16 annual cases. At the 5 percent level there are 11 quarterly rejections and 8 annual rejections. The evidence is thus mixed for the annual cases and generally against the restriction for the quarterly cases. At least for the quarterly cases, then, the standard view as reflected in equation (5) is doubly rejected. The change form itself is overwhelmingly rejected, and within the change form the summation restriction is generally rejected.

4 Long-Run Implications

It is of interest to compare the policy implications of two versions of equations (8) and (9). This is done for the U.S. equations in Table 5. The first set of results is for the two U.S. equations in Tables 1 and 3. The experiment is a sustained decrease in the unemployment rate beginning in 1993:3, using as initial conditions the actual values for 1993:2 back. The base prediction path takes the unemployment rate to be equal to its 1993:2 value for all future periods, and the new prediction path takes the unemployment rate to be one percentage point lower than this value for all future periods. In both cases the price of imports is taken to grow at the same rate as the price level.

The first set of results in Table 5 shows that after 12 quarters the price level is 2.32 percent higher in the new case. Inflation in the first year is about .9 percentage points higher (at an annual rate). It is about .75 percentage points higher in the second year

Table 5
Policy Implications

Quar.	$\frac{P^{new}}{P^{base}}$	$\Delta p^{new} - \Delta p^{base}$	$\frac{P^{new}}{P^{base}}$	$\Delta p^{new} - \Delta p^{base}$
1	1.0024	.97	1.0025	1.02
2	1.0047	.92	1.0051	1.02
3	1.0069	.88	1.0077	1.02
4	1.0090	.83	1.0103	1.02
5	1.0111	.80	1.0129	1.02
6	1.0130	.76	1.0155	1.02
7	1.0148	.73	1.0181	1.02
8	1.0166	.70	1.0207	1.02
9	1.0184	.68	1.0233	1.02
10	1.0200	.65	1.0260	1.02
11	1.0216	.63	1.0286	1.02
12	1.0232	.61	1.0312	1.02
100	1.0742	.05	1.2920	1.02
∞	1.0795	.00	∞	1.02

P = price level, $p = 400 \log P$
Unemployment rate is one percentage point lower for new than base.

and .65 percentage points higher in the third year. After 100 quarters the price level is 7.42 percent higher, and the inflation rate is .05 percentage points higher. The very long run implications are that the price level is 7.95 percent higher and the inflation rate is back to that in the base case.

Now consider the version of equation (8) used for the sixth test in Table 2 and the version of equation (9) used for the fifth test in Table 4 (which is equation (14)). These are the versions consistent with the original Phillips curve. The second set of results in Table 5 is for these two versions, based on the same experiment as for the first set. After 12 quarters the price level, new versus base, is 3.12 percent higher. The inflation rate is always 1.02 percentage points higher. After 100 quarters the price level is 29.20 percent higher, and as time marches on the differences in the price levels become larger and larger.

What is interesting about the two sets of results in Table 5 is how close they are for the first 12 quarters. Even though the long-run implications are vastly different, the short-run implications are fairly similar. One would be hard pressed to choose between the two sets of equations on the basis of which short-run implications seem more “reasonable.” Instead, one needs tests of the kind performed in this paper.

The policy implications of equations like (5) are, of course, quite different. If, for example, the unemployment-rate change is a negative change from the natural rate, the inflation rate increases each period, and if it is a positive change, the inflation rate decreases each period.

5 Conclusion

The main conclusion of this paper is that the data fairly strongly support (8), the level form of the price equation, and very strongly reject the standard view as reflected in equation (5).

As noted in Section 1, if this conclusion is valid, it changes the way one thinks about the trade-off between inflation and unemployment, but it does not have to imply that unemployment can be driven to very low levels with only a modest effect on the price level. There may be a strongly nonlinear relationship between the price level and unemployment at low levels of unemployment. Unfortunately, it is hard to estimate the level of the unemployment rate at which further decreases would lead to large increases in the price level because there are so few observations of very low unemployment rates.

The results of searching over the different functional forms of the demand pressure variables did not single out for attention a particular functional form. If anything, the linear form gave the best results, which shows the difficulty of estimating anything nonlinear. It would not be trustworthy to use the chosen price equations in this paper to predict what the price level would be with demand pressure much tighter than existed historically. [16]

Given the difficulty of estimating where the severe nonlinear zone begins, policy makers are faced with a hard problem. There are too few high-activity observations for any confidence to be placed on the point at which output should not be pushed further without severe price-level consequences. The results in this paper are of little help regarding this question. The main point of this paper for policy makers is that they should not think there is some unemployment rate below which inflation forever accelerates and above which it forever decelerates. They should think instead that the price level is a negative function of the unemployment rate, where at some point the function begins to become severely nonlinear. How bold a policy maker is in pushing the unemployment rate into uncharted waters will depend on how fast he or she thinks the nonlinearity becomes severe.

[16] Staiger, Stock, and Watson (1996), using equations like (5), estimate variances of Nairu estimates and find them to be very large. From the point of view of this paper, equations like (5) are highly misspecified, and there is no Nairu. It is thus not necessarily surprising that large estimated variances result when the Nairu is assumed to exist and equations like (5) are used. Similarly, Eisner (1995), using equations like (5), finds them sensitive to various assumptions, particularly assumptions about whether the behavior of inflation is symmetric for unemployment rates above and below the assumed Nairu. Again, this sensitivity is not surprising if the basic equations used are highly misspecified. It is clear from Eisner's paper that although he is working with price equations in change form (and usually in a form like (5) where the coefficients of the right-hand side nominal variables sum to one), he does not like the concept of the Nairu. The results in this paper suggest that his doubts are well founded—he should be working with price equations in level form.

Appendix

An important question in a study like this is whether the asymptotic distributions that are used for inferences are good approximations of the exact distributions. In some unit-root cases they are not. Fortunately, this question can be examined using stochastic simulation. Exact distributions can be computed and then compared to the asymptotic distributions.

Regarding the last test in Table 2, namely the test that $\beta_1 + \beta_2 + \beta_3 = 1$ in equation (15), the following experiment was run using U.S. data. First, equation (15) was estimated by 2SLS under the assumption that $\beta_1 + \beta_2 + \beta_3 = 1$. (The U.S. estimation period is 1954:1–1995:3.) The coefficients were estimated along with the variance of the error term. Call this the "base" equation. The error term is assumed to be normally distributed with mean zero and variance equal to the estimated variance. The stochastic simulation procedure is then as follows:

1. Using the normality assumption and the estimated variance, draw a value of the error term for each quarter in the estimation period. Add these error terms to the base equation and solve it dynamically to get new data for p. Given the new data for p and the other necessary data (which have not changed), test the hypothesis that $\beta_1 + \beta_2 + \beta_3 = 1$. This is done by estimating the equation (by 2SLS) with and without the constraint and computing the χ^2 value. Record this value.

2. Do step 1 J times, which give J χ^2 values. Call the distribution of these values the "exact" distribution.

3. Compute the percent of the χ^2 values that are greater than the critical value of

k percent, and compare how close the computed percent is to k.

This was done for $J = 10,000$. For $k = .500$ the percent of the χ^2 values above the critical value was .503. For $k = .200$ the percent was .207; for $k = .100$ the percent was .104; for $k = .050$ the percent was .049; for $k = .020$ the percent was .022; and for $k = .010$ the percent was .011. It is clear that the asymptotic distribution is very close to the exact distribution. Using the asymptotic theory in the present case does not seem likely to lead to incorrect conclusions. A similar conclusion was reached in Fair (1994) regarding the use of the 2SLS estimator to estimate macroeconometric models.

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